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FORECASTING CHRISTCHURCH URBAN ELECTRICITY DEMAND AND ENERGY USING DAY-TYPE CORRECTIONS

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Forecasting Christchurch Urban Electricity Demand and Energy Consumption Using Day-Type Corrections

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Abstract: Customized electricity-forecasting models are developed to predict short to mid-term electricity demand and energy consumption, to reflect Christchurch's unique load structure and weather characteristics. The developed forecasting models employ weather and day-type correlation, by taking into consideration historical load and weather data with respect to different type of days, such as Workdays, Saturday, Sunday, Public Holidays, and the concept of linear-proportionality between temperature and load demand. It is observed that the Christchurch urban area has a winter peaking characteristic, with the highest and lowest daily average load demand and energy consumption occurring on each working Monday or Tuesday and Sunday/Public Holiday respectively.

1. INTRODUCTION

Forecasting electricity load is an important and on going economic problem. The reformed New Zealand energy markets are becoming more competitive, and utility companies are increasingly aware of the need for improved forecasting data of both anticipated system loads and wholesale/retail spot price of electricity, as failure to implement efficient forecasts can result in multimillion-dollar losses [1-2]. Accurate forecasting models for electric power load are essential to the operation and planning of utility companies, as demand is a major determinant of the electricity wholesale/retail spot price. Load forecasting is important for contract evaluations and evaluations of various sophisticated financial products on energy pricing offered by the market [2].

Electricity loads are highly predictable, due to their strong daily, weekly and yearly periodic behaviour, and variance across season with respect to temperature. Most long and short-term load predictions are based on complex mathematical and statistical models [3-7].

The accuracy of load forecasting depends not only on the load forecasting techniques, but also on the accuracy of time, forecasted weather and customers' classes. The time factors include the time of the year, the day of the week and the hour of the day. There are important differences in load between weekdays and weekends. The load on different weekdays also can behave differently. For example, Mondays and Fridays being adjacent to weekends, may have structurally different loads than Tuesday through Thursday. Holidays are more difficult to forecast than non-holidays because of their relative infrequent occurrence. Furthermore, forecasted weather parameters are the most important factors in short-term load forecasts, which include various weather variables. For example, temperature and humidity are the most commonly used load predictors. The electricity usage pattern is different for customers that belong to different classes, such as residential, commercial and industrial, however it is similar for customers within each class.

In this paper, an alternative methodology [8] using weather and day-type correction of electricity loads from historical data, is applied to Christchurch's unique load structure and weather characteristics to forecast short to mid-term electricity usage. The approach demonstrates the analysis of the impacts on load of day-type effects (leap years, differing mixes of workdays and weekends from month to month, the timing of Easter and other Public Holidays) and of various weather measures (Temperature, Heating Degree Days and Cooling Degree Days).

2. PROCEDURE

A flow-chart of the proposed procedure for forecasting electricity demand and energy consumption is shown in Figure 1.

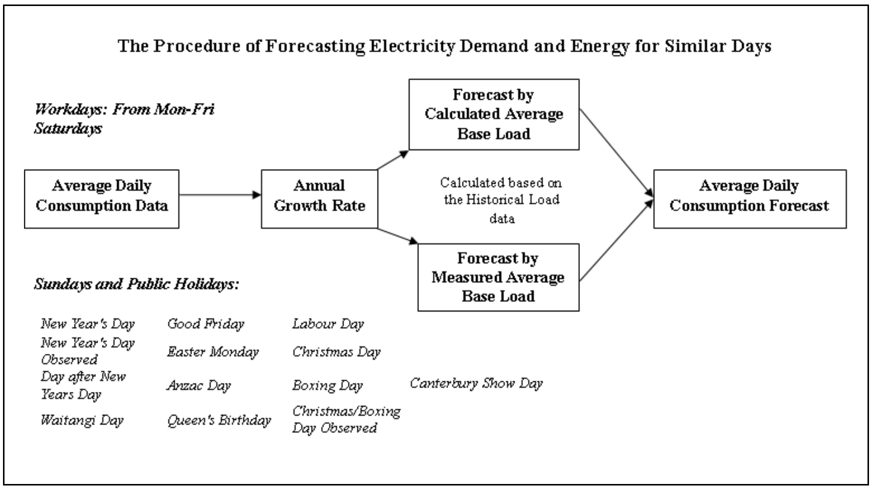

Figure 1 *The Procedure of Forecasting Electricity Demand and Energy Consumption*

I. Region Definition and Historical Data Analysis

The Christchurch's Orion Limited supplied five years of Christchurch urban area (Zone A) network demand averages, recorded at half-hour intervals from 1^{st} April 2002 to 31^{st} December 2007. The University of Canterbury Geography Department has weather data of temperature, humidity, rainfall, for the corresponding period. This historical load data were analysed on a daily basis for average, maximum, minimum half-hour load demand and energy consumption, then divided into manageable sequential groups of yearly, monthly, weekly load data, and further separating these load data into day-type electricity loads of Workdays (Monday-Friday), Saturday, Sunday and Public Holidays.

II. Day-Type Correction of Energy Loads (Time Factors)

As electricity loads are higher on workdays than non-workdays, it is necessary to isolate each day-type impacts to obtain an accurate estimate of demand and energy forecast. Thus a more precise Day-type Correlation model is formed with respect to the existing Australian forecasting model derived by Patrick Gannon [8], and a comparison of the New Zealand forecasting model is made with actual recorded load data from Orion for accuracy and modification.

III. Seasonal Forecast Model (Time and Weather Factors)

Finally, by analysing and comparing the historic load demand with the forecasted load, a seasonal model is developed. This, combined with characteristics which include weather, day of the week and the date, is considered as a forecast, as shown in Figure 2.

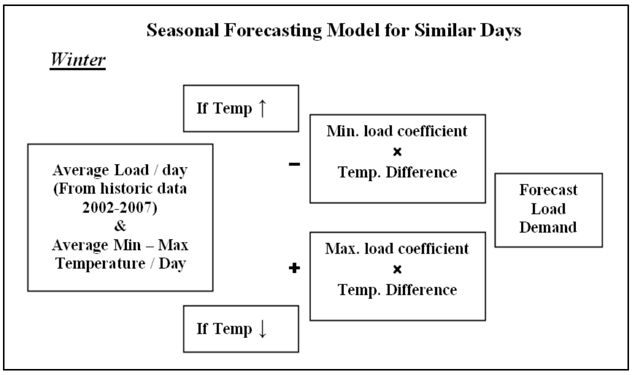

Figure 2 *Seasonal Forecasting Model*

3. METHODOLOGY

The load forecasting model depends on past and current information regarding variables that affect electricity loads for a period, as illustrated in Equation (1). Therefore, a forecasting system can be derived which obtains and analyzes historical data, pre-processes and normalizes the information, determines a suitable mathematical model and finally, ascertains the forecast.

Total Load *= Normal Load + Special Event Load + Weather Sensitive Load* **(1)**

3.1 Region and Historical Load Data Analysis

Orion's historical data were extracted and sorted into sequential yearly, monthly and weekly groups for analysis. The average Monday half-hour load demand from 1st April 2002 to 5th May 2007 is shown in Figure 3.

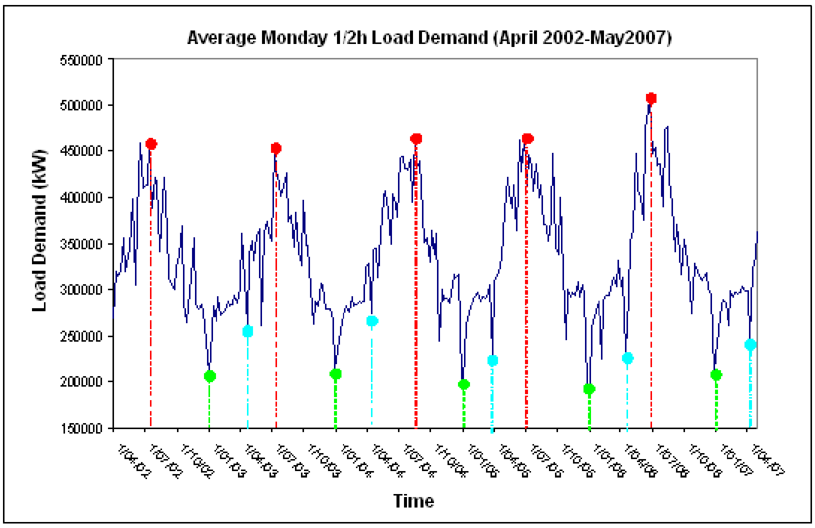

Figure 3 *2002-2007 Average Monday Half-hour Load Demand*

It is observed that the maximum (red dots) and minimum (green dots) load demand occur in July and January every year. This corresponds to winter and the Christmas/New Year period respectively. Apart from these peaks, there is a relatively stable load demand in summer from November to February and an annual growth towards the winter load demand from March to July. From August to October the load declines to its summer value.

The second lowest load demand period occurs during in April, i.e. the Easter period (blue dots). This sequential pattern demonstrates that load demand in the Christchurch urban area follows a highly periodical behaviour with respect to the time of year, which is the dominating factor of the proposed forecast model.

3.2 Day-type Correction Method

The Day-type correction procedure calculates average day-type energy for each month and determines standard monthly day-type mixes. The estimation of the day-type impact on each month's load can be calculated as in Equation (2), the definition of variables are shown in the Appendix:

$$Conrrection_{Day-type} = L_W(n_W^S - n_W^A) + L_{Sat}(n_{Sat}^S - n_{Sat}^A) + L_{Sun+Hol}(n_{Sun+Hol}^S - n_{Sun+Hol}^A) \quad \textbf{(2)}$$

To analyze day-type load demand, different days of the week are separated into Workdays, (i.e. Monday~Friday), Saturday, Sunday and Public Holidays. A standard day-type table developed for this project is shown in Table 1. The demand and energy forecast on each day is calculated with respect to the number of different day types and public holidays in each month of the year.

Table 1 *Standard Numbers of Workdays, Saturdays and Sundays/Public Holidays by Day*

Standard Numbers of Workdays, Saturdays and Sundays/Public Holidays by Day									
Month			Workdays				Sat	Sun & P. Hol	Total
	Mon	Tue	Wed	Thur	Fri	Total			
January	4	4	4	4	5	21	4	6	31
February	4	4	4	4	4	20	4	4	28
March	5	5	4	4	4	22	4	5	31
April	3	4	4	4	4	19	4	7	30
May	4	4	4	5	5	22	5	4	31
June	5	4	4	4	4	21	4	5	30
July	4	4	4	5	5	22	5	4	31
August	4	4	4	5	5	22	5	4	31
September	4	4	4	4	5	21	5	4	30
October	5	4	5	4	4	21	5	5	31
November	5	4	4	4	4	21	4	5	30
December	4	4	4	4	4	20	4	7	31
Total	51	49	49	51	53	252	53	60	365

4. RESULTS AND DISCUSSION

4.1 Day-type Correlation Model

The number of Workdays, Saturdays and Sundays/Public Holidays for 2008 are shown in Table 2. Day-type average, maximum half-hour load demands and energy consumption are analysed on a daily basis, which are shown in Table 3, 4 and 5 respectively. The comparison of these day-type average loads correlate well with historical load data, recorded from 1st April 2002 to 31st December 2007, i.e. the lowest and highest load demand and energy consumption occur monthly in January and July, weekly in workdays and non-workdays. From these analysed day-type loads, it is observed that peak load demand and energy consumption is determined by Workdays' loading structure, with lowest load demand and energy consumption occurring on Saturday, Sunday and Holidays respectively.

Table 2 *Number of Workdays, Saturdays and Sundays/Public Holidays in 2008*

2008 Standard Numbers of Workdays, Saturdays and Sundays/Public Holidays									
Month	Workdays						Sat	Sun & Holidays	Total
	Mon	Tue	Wed	Thur	Fri	Total			
January	4	4	4	5	4	21	4	6	31
February	4	4	3	4	5	20	4	5	29
March	4	4	4	4	4	20	5	7	32
April	4	5	5	4	3	21	4	5	30
May	4	4	4	4	5	21	5	4	30
June	4	4	4	4	4	20	4	6	30
July	4	5	5	5	4	23	4	4	31
August	4	4	4	4	5	21	5	5	31
September	5	5	4	4	4	22	4	4	30
October	3	4	5	5	5	22	4	5	31
November	4	4	4	4	4	20	5	5	30
December	5	5	5	3	3	21	4	6	31
Total	49	52	51	50	50	252	52	62	366

Table 3 *Day-type Average 1/2h Load Demand*

Daily Average 1/2h Load Demand for Standard Number of Workdays, Saturdays and Sundays/Public Holidays							
Month	Workdays (kW)					Sat	Sun & P. Hol
	Mon	Tue	Wed	Thur	Fri	(kW)	(kW)
January	270986	274198	270403	270437	263768	221415	209341
February	286265	291107	289687	290905	283516	234307	225908
March	299494	304776	306322	302029	292484	243920	237060
April	325342	331548	327794	329102	320983	270389	264807
May	370129	373610	369039	367582	356681	302009	301577
June	424816	426964	427715	428436	412123	356930	342434
July	433324	436842	435466	435441	429947	378785	365654
August	414261	419342	415195	410288	399485	343244	336062
September	355558	368686	365289	360256	346069	293534	289925
October	335097	335352	336255	325737	308972	267269	272921
November	304672	309152	303249	300348	243011	243011	247908
December	285874	285833	279987	283207	267722	234858	227125

Table 4 *Day-type Average Maximum 1/2h Load Demand*

Daily Maximum 1/2h Load Demand for Standard Number of Workdays, Saturdays and Sundays/Public Holidays							
Month	Workdays (kW)					Sat	Sun & Holidays
	Mon	Tue	Wed	Thur	Fri	(kW)	(kW)
January	330525	330999	327341	325582	321856	267349	259708
February	346162	351034	348809	351328	347610	282689	277613
March	369865	372808	372968	368653	362677	296312	302947
April	411867	411902	405913	408029	393911	341900	351312
May	469570	471245	463943	456865	437612	389762	404153
June	518393	511773	512550	512116	499494	449299	447155
July	521143	519086	517828	518502	514972	467011	467142
August	503181	503587	502414	500927	487581	425861	434998
September	436708	450447	446496	443106	423576	360069	379158
October	422053	415691	423629	401094	377553	323629	411138
November	374772	380412	370368	363971	359859	294669	305428
December	349213	344159	339352	343002	328454	288284	281925

From historical load data, the same day-type correction technique is employed to obtain day-type average and maximum half-hour load demand for standard number of Workdays, Saturday, Sunday and Public Holiday. These average load demands give an indication on the expected range of average and maximum load demand for different day types in each month.

Day-type average energy consumption is the expected daily average energy usage for different day types in each month. Correlation models are the calculated day-type base loads for the forecasting model.

Table 5 *Day-type Average Energy Consumption*

Daily Average Energy Consumption for Standard Number of Workdays, Saturdays and Sundays/Public Holidays									
Month	Workdays (GWh)					Total	Sat	Sun & Holidays	Total
	Mon	Tue	Wed	Thur	Fri	(GWh)	(GWh)	(GWh)	(GWh)
January	6.504	6.581	6.490	6.490	6.330	32.395	5.314	4.985	42.694
February	6.870	6.987	6.952	6.982	6.804	34.596	5.623	5.422	45.641
March	7.188	7.315	7.352	7.249	7.020	36.123	5.854	5.689	47.666
April	7.808	7.957	7.867	7.898	7.704	39.234	6.489	6.355	52.079
May	8.883	8.967	8.857	8.822	8.560	44.089	7.248	7.238	58.575
June	10.196	10.247	10.265	10.282	9.891	50.881	8.566	8.218	67.666
July	10.400	10.484	10.451	10.451	10.319	52.104	9.091	8.776	69.971
August	9.942	10.064	9.965	9.847	9.588	49.406	8.238	8.065	65.709
September	8.533	8.848	8.767	8.646	8.306	43.101	7.045	6.958	57.104
October	8.062	8.048	8.070	7.818	7.415	39.413	6.414	6.550	52.378
November	7.312	7.420	7.278	7.208	6.896	36.114	5.832	5.950	47.896
December	6.861	6.860	6.720	6.797	6.425	33.663	5.637	5.451	44.751
Total(GWh)	98.559	99.778	99.034	98.490	95.258	491.119	81.352	79.658	652.129

Table 6 is the calculated results for 2008 monthly day-type average energy consumption forecast, corresponding to the standard day-type correlation models shown in Table 2 and 5. It is the expected energy usage based on the correlation between historical load data with day-type mixes of Workdays, Saturday and Sunday/Public Holiday in monthly terms.

Table 6 *2008 Monthly Day-type Average Energy Consumption Forecast*

Forecasted Monthly 2008 Day-type Average Energy Consumption for Standard Number of Workdays, Saturdays and Sundays/Public Holidays									
Month	Workdays (GWh)					Total	Sat	Sun & Holidays	Total
	Mon	Tue	Wed	Thur	Fri	(GWh)	(GWh)	(GWh)	(GWh)
January	26.015	26.323	25.959	32.452	25.322	136.071	21.256	29.912	187.238
February	27.481	27.946	20.857	27.927	34.022	138.234	22.493	27.109	187.836
March	28.751	29.258	29.407	28.995	28.078	144.490	29.270	39.826	213.586
April	31.233	39.786	39.335	31.594	23.111	165.059	25.957	31.777	222.793
May	35.532	35.867	35.428	35.288	42.802	184.916	36.241	28.951	250.109
June	40.782	40.989	41.061	41.130	39.564	203.525	34.265	49.310	287.101
July	41.599	52.421	52.256	52.253	41.275	239.804	36.363	35.103	311.270
August	39.769	40.257	39.859	39.388	47.938	207.210	41.189	40.327	288.727
September	42.667	44.242	35.068	34.585	33.223	189.784	28.179	27.833	245.797
October	24.185	32.194	40.351	39.088	37.077	172.894	25.658	32.751	231.303
November	29.249	29.679	29.112	28.833	27.583	144.455	29.161	29.749	203.366
December	34.305	34.300	33.598	20.391	19.276	141.870	22.546	32.706	197.122
Total(GWh)	401.568	433.261	422.290	411.923	399.270	2068.313	352.581	405.354	2826.248

4.1.1 Day-type Correlation Model with Underlying Growth Rate

The Day-type correlation forecasting model is based on averaging the historical day-type load data. It assumes a similarity within monthly day-type load demand and energy consumption from year to year, which result in ignoring any underlying growth trend. This means that the forecasted values for 2008 monthly day-type average energy consumption shown in Table 6 is an inaccurate forecast, with predicted values lower than actual measured values. Calculation of the underlying monthly day-type growth rate is essential to accurately predict and forecast load demand and energy consumption. Based on the historical data provided by Orion, the monthly day-type growth rates between each year are calculated. Except for the unavailable historical data from January to March in 2002, the annual monthly day-type growth rates from April 2002 to 2007 are all identified.

Shown in Table 7 and 8 are the average underlying load growth rate for day-type average and maximum half-hour load demand, which are calculated from historical sequential weekly day-type growth rates. The predicted average and maximum half-hour load demand in 2008 with the underlying growth rate are presented in Table 9 and 10. From data analysis, it is observed that the average energy consumption follows the same growth trend as day-type average load demand underlying growth rates presented in Table 7. Thus the forecasted daily and monthly day-type energy consumption are shown in Table 11 and 12.

Table 7 *Day-type Underlying Load Growth Rate for 1/2h Average Load Demand*

Average Day-type Underlying Growth Rate April 2002-2007 for Standard Number of Workdays, Saturdays and Sundays/P.H							
Month			Workdays (%)			Sat	Sun & Holidays
	Mon	Tue	Wed	Thur	Fri	(%)	(%)
January	1.023	1.184	1.205	0.768	1.919	2.029	3.233
February	0.865	1.427	1.505	1.204	1.706	1.975	1.878
March	0.852	1.544	2.438	1.931	1.368	0.951	1.269
April	0.302	-0.036	0.838	1.337	2.686	2.424	0.764
May	0.272	0.964	1.073	0.222	0.205	0.472	0.326
June	1.599	2.307	2.311	2.527	1.527	1.221	2.871
July	1.984	1.870	1.201	1.365	1.561	2.402	2.320
August	1.697	2.047	2.714	1.898	1.115	2.087	1.151
September	3.437	4.304	4.281	3.517	2.246	1.794	3.122
October	-0.345	1.291	3.032	1.490	-2.083	1.795	4.805
November	0.094	-0.276	0.565	0.060	-2.366	-0.627	4.580
December	1.805	1.995	0.365	-0.483	-0.550	1.522	5.719

Table 8 *Day-type Underlying Load Growth Rate for 1/2h Average Maximum Load Demand*

Maximum Day-type Underlying Growth Rate April 2002-2007 for Standard Number of Workdays, Saturdays and Sundays/P.H							
Month			Workdays (%)			Sat	Sun & Holidays
	Mon	Tue	Wed	Thur	Fri	(%)	(%)
January	0.788	1.096	1.107	0.899	2.131	1.420	4.400
February	1.031	1.472	1.561	1.005	1.610	1.158	2.485
March	-0.132	1.262	2.275	2.470	1.962	0.634	1.349
April	-0.179	-0.345	0.840	1.615	2.640	2.469	-0.069
May	0.309	1.535	1.298	0.222	0.177	-0.223	0.156
June	1.298	2.039	2.463	2.868	1.752	0.397	2.119
July	2.094	2.142	1.986	2.112	2.076	1.932	1.861
August	2.355	2.327	2.666	2.045	1.377	0.425	0.180
September	2.983	4.984	4.552	3.455	2.681	-0.077	1.539
October	-0.601	0.735	3.719	1.731	-2.303	1.274	16.467
November	-0.551	-0.308	-0.029	0.179	-2.827	-0.963	3.354
December	2.596	2.280	0.554	0.139	-0.645	1.604	4.516

Table 9 *2008 Forecast for Day-type 1/2h Average Load Demand*

2008 Forecasted Day-type Average Load Demand with Underlying Growth Rate							
Month		Workdays (kW)				Sat	Sun & Holidays
	Mon	Tue	Wed	Thur	Fri	(kW)	(kW)
January	277537	281305	278896	274885	273259	232417	225551
February	289218	299605	297709	297377	292562	243905	234017
March	301660	311066	319664	312008	297448	246591	240678
April	328666	325889	329812	334458	340949	286576	264637
May	360941	373825	372108	366093	356459	300940	296604
June	437269	449379	450197	453321	425250	368560	365430
July	456319	457600	447283	451141	444297	401873	386378
August	425348	437646	434909	421709	404380	355428	340100
September	377785	399018	400256	386140	361035	303123	306142
October	328788	341850	358928	336490	286476	273193	310172
November	309250	312629	308633	296486	263467	240345	286671
December	286141	287915	283688	277052	252255	236044	261904

Table 10 *2008 Forecast for Day-type 1/2h Average Maximum Load Demand*

2008 Forecasted Day-type Maximum Load Demand with Underlying Growth Rate							
Month	Workdays (kW)					Sat	Sun & Holidays
	Mon	Tue	Wed	Thur	Fri	(kW)	(kW)
January	337128	339441	337117	331728	334152	279343	287617
February	350788	361786	359334	357546	358101	292098	295839
March	365925	376208	386288	383944	371241	296677	309322
April	412130	402657	408518	418558	418280	362343	345475
May	458330	479556	471095	454864	441500	383512	397584
June	534079	537048	541182	544891	518070	457111	470801
July	547161	543327	540363	542621	539965	491566	489405
August	525692	532166	531198	522834	498108	430107	433123
September	456644	495966	495414	475219	445341	359222	391197
October	411375	418729	457856	421862	346709	332037	472932
November	375882	385419	372808	360818	323271	293641	344219
December	350280	350012	344717	340943	305501	292129	317559

Table 11 *2008 Forecast for Daily Day-type Average Energy Consumption*

Forecasted Daily 2008 Day-type Average Energy Consumption with Underlying Growth Rate									
Month	Workdays (GWh)					Total	Sat	Sun & Holidays	Total
	Mon	Tue	Wed	Thur	Fri	(GWh)	(GWh)	(GWh)	(GWh)
January	6.661	6.751	6.694	6.597	6.558	33.261	5.578	5.448	44.287
February	6.941	7.191	7.145	7.137	7.021	35.435	5.854	5.616	46.905
March	7.240	7.466	7.672	7.488	7.139	37.004	5.918	5.776	48.699
April	7.888	7.821	7.915	8.027	8.183	39.835	6.878	6.351	53.064
May	8.663	8.972	8.931	8.786	8.555	43.906	7.223	7.118	58.247
June	10.494	10.785	10.805	10.880	10.206	53.170	8.845	8.770	70.786
July	10.952	10.982	10.735	10.827	10.663	54.159	9.645	9.273	73.077
August	10.208	10.504	10.438	10.121	9.705	50.976	8.530	8.162	67.668
September	9.067	9.576	9.606	9.267	8.665	46.182	7.275	7.347	60.804
October	7.903	8.204	8.614	8.076	6.875	39.672	6.557	7.444	53.673
November	7.422	7.503	7.407	7.116	6.323	35.771	5.768	6.880	48.420
December	6.867	6.910	6.809	6.649	6.054	33.289	5.665	6.286	45.240
Total (GWh)	100.306	102.665	102.770	100.972	95.948	502.661	83.736	84.473	670.870

Table 12 *2008 Forecast for Monthly Day-type Average Energy Consumption*

Forecasted Monthly 2008 Day-type Average Energy Consumption with Underlying Growth Rate									
Month	Workdays (GWh)					Total	Sat	Sun & Holidays	Total
	Mon	Tue	Wed	Thur	Fri	(GWh)	(GWh)	(GWh)	(GWh)
January	26.644	27.005	26.774	32.986	26.233	139.642	22.312	32.686	194.640
February	27.765	28.762	21.435	28.548	35.107	141.618	23.415	28.082	193.115
March	28.959	29.862	30.688	29.953	28.555	148.017	29.591	40.434	218.042
April	31.552	39.107	39.577	32.108	24.548	166.892	27.511	31.756	226.160
May	34.650	35.887	35.722	35.145	42.775	184.180	36.113	28.474	248.767
June	41.978	43.140	43.219	43.519	40.824	212.680	35.382	52.622	300.684
July	43.807	54.912	53.674	54.137	42.652	249.182	38.580	37.092	324.854
August	40.833	42.014	41.751	40.484	48.526	213.608	42.651	40.812	297.072
September	45.334	47.882	38.425	37.069	34.659	203.370	29.100	29.390	261.859
October	23.708	32.818	43.071	40.379	34.377	174.352	26.227	37.221	237.800
November	29.688	30.012	29.629	28.463	25.293	143.085	28.841	34.400	206.327
December	34.337	34.550	34.043	19.948	18.162	141.039	22.660	37.714	201.414
Total (GWh)	409.255	445.952	438.008	422.738	401.712	2117.665	362.383	430.683	2910.732

Graphical interpretation of the correlation between forecasted workday average and maximum half-hour load demand are shown in Figure 5 and 6. Without the implementation of day-type underlying growth rates, the day-type correlation model ignores fundamental load growth, resulting in a lower forecast demand in 2008 (green solid line). This demonstrates that the day-type correlation model alone produces an inaccurate forecast of load demand. However, the day-type correlation model with incorporated underlying day-type growth rate in the forecast model gives a more realistic load demand forecast for 2008 (red solid line). Thus, the latter (2008 forecast with underlying growth rate) is a more suitable prediction model for the 2008 average and maximum load demand.

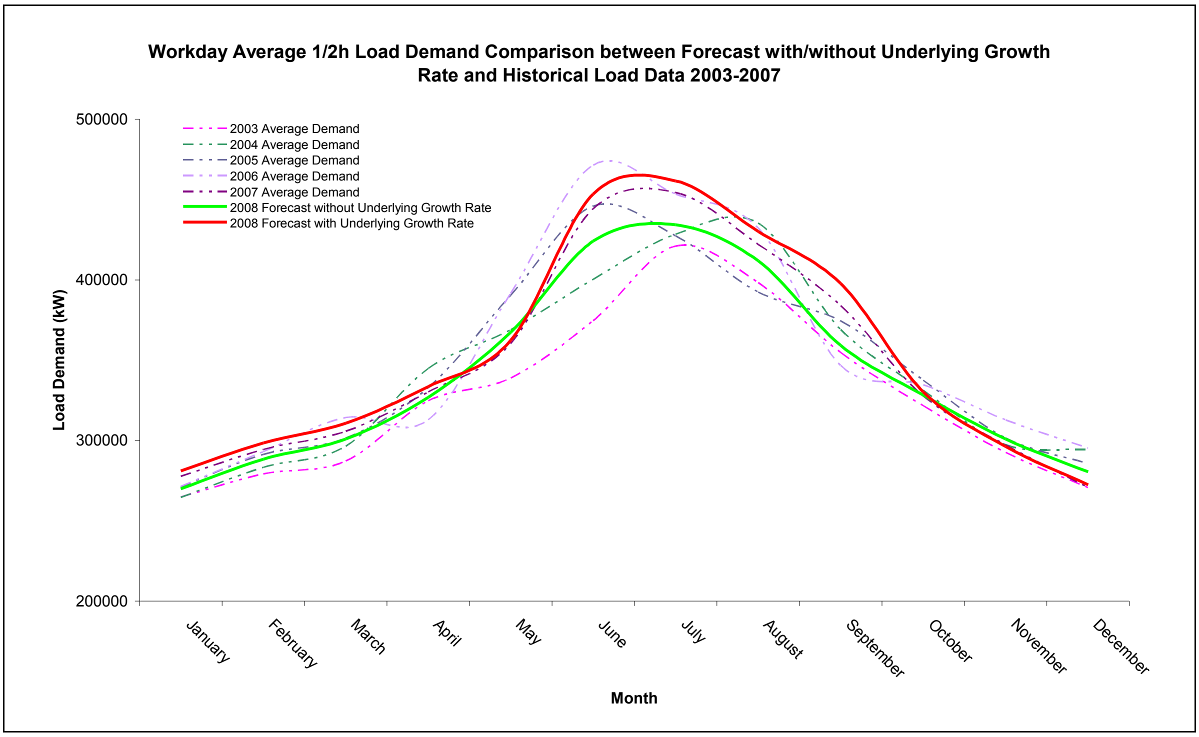

Figure 5 *Workday Average Load Demand Comparison of 2008 Forecast with and without Underlying Growth Rate, and Historical Data from 2003 to 2007*

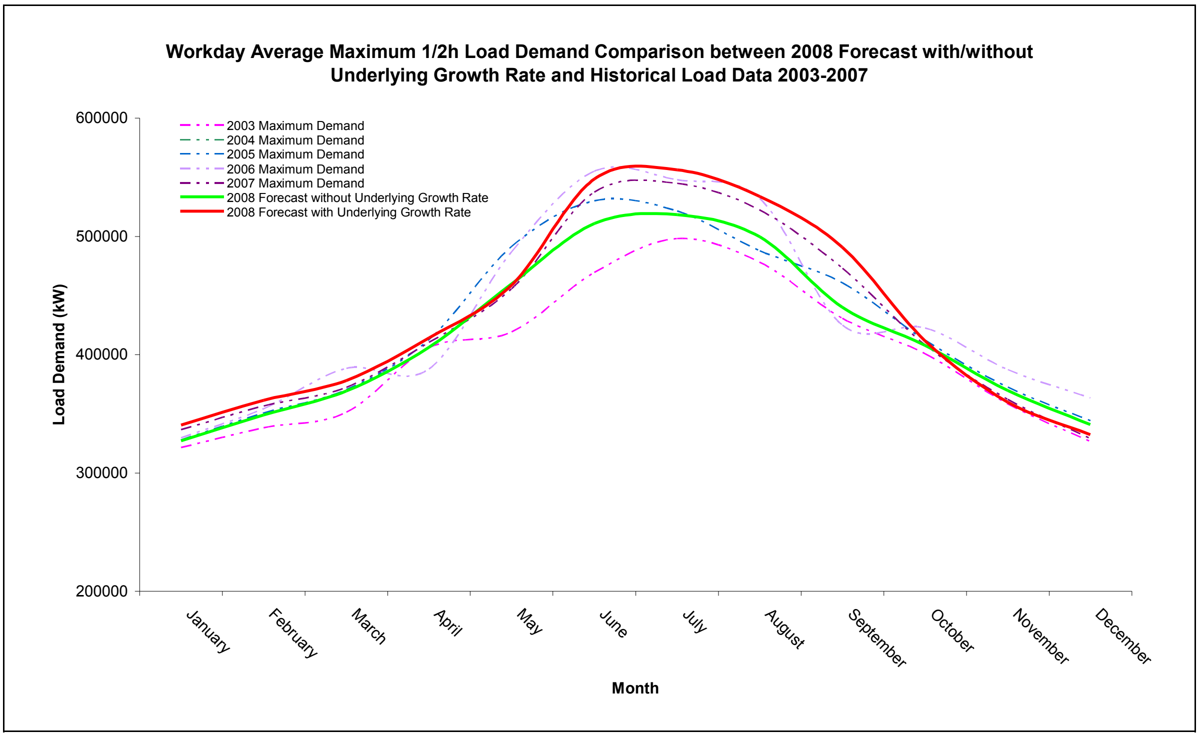

Figure 6 *Workday Maximum Load Demand Comparison of 2008 Forecast with and without Underlying Growth Rate, and Historical Data from 2003 to 2007*

Figure 7 presents the comparison of the forecasted day-type average, maximum half-hour load demand and daily energy consumption with actual recorded data from 1st January- 30th March 2008. From extensive data analysis, model derivation and validation, it is observed that to obtain a more realistic forecast, two different types of day-type correlation forecasting models need to be developed, with the first being a forecast model derived from historical load data and long-term growth trend, and the second being a forecast model derived with previous year's load data and long-term growth trend.

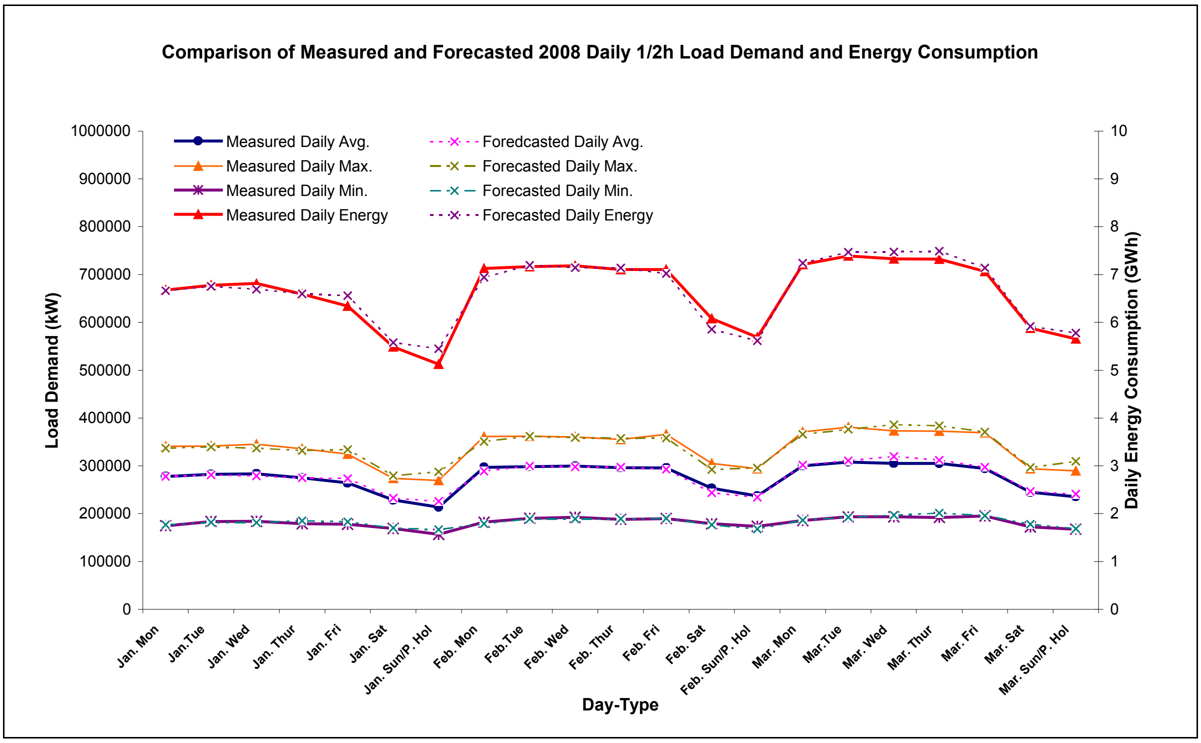

***Figure** 7 Comparison of 2008 Recorded and Forecasted Day-type Average, Maximum Load Demand and Energy Consumption*

Due to the averaging nature of the day-type correlation model, it is advisable to include a 2~5% error margin to account for extremities that have been minimized by this forecasting method.

4.1.2 Improved Day-type Correction Model

To increase the accuracy of the day-type correction model, a more precise model has been developed. This model is based on the observation of load variation between the same day-type loads, an inter and intra-season load fluctuation can be seen from similar weekdays within each month, giving noticeable load demand and energy consumption deviation between the 1st, 2nd, 3rd, 4th, 5th weekdays of the month, i.e. the load demand and energy consumption for the 1st Monday of January is different to that for the 1st Monday of July, thus there is an inter-seasonal variation due to summer and winter loading structure. Moreover, the load demand of the 1st Monday of January is different to that of the 2nd Monday of January, thus there is an intra-seasonal variation due to the different public holiday and workday loading structure.

To convey this seasonal variation, the daily average half-hour load demand for each consecutive weekday is calculated. This improved day-type correlation model is shown in Table 13, which forecasts the average daily day-type load demand rather than the average weekly day-type load demand. However, without calculating the underlying growth rate between each consecutive weekday, these daily load averages can only be used as a base value to forecast load demand. Calculations of underlying growth rate for the improved day-type correction require obtaining both horizontal and vertical growth rate for each days of the month. A horizontal growth rate is present between different weekdays, i.e. Monday to Sunday. A vertical growth rate is present between the same weekdays, i.e. 1st Monday to the 5th Monday. Both of the growth rates are required for all 365 days to give an accurate daily load forecast.

To date the underlying growth rates for the improved day-type correlation model has not been fully calculated, however, this method should prove to be a more accurate day-type forecast model, with the precision and accuracy to predict average load demand for a specific day.

Table 13 *Daily Average 1/2h Load Demand for Consecutive Weekdays by Month*

	L_{AVG} *(kW)*						
January	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sun/P.Hol
1st	218687	223768	228318	219433	223047	201177	195662
2nd	262677	267291	264996	263831	259455	222462	216769
3rd	271163	276144	280561	276504	270838	224223	216374
4th	284247	286154	285070	283139	280658	231111	221768
5th	287190	290206	284872	279736	273794	233490	225514
February	L_{AVG} *(kW)*						
1st	266446	275532	284779	273522	265089	227285	221865
2nd	286601	291213	291033	291471	284109	232628	225717
3rd	288357	293447	290553	291576	284654	234076	230306
4th	290108	291173	292383	294218	287756	243239	227290
5th							228007

4.2 Seasonal Forecast Model

For this model, it is assumed that the load demand is linearly proportional to the change of temperature, i.e. in Summer a temperature increase will lead to a load demand increase. In contrast, Winter loading is inverse-linearly proportional to a temperature increase. Equation (3) demonstrates that if the average temperature (*t*) is higher than the standard average temperature (t_{AVG}) in summer, the load demand can be calculated using (see Appendix for definition of variables):

$$L = L_{AVG} + (t - t_{AVG})K_H \qquad \textbf{(3)}$$

However, if the average temperature is lower, the load demand can be determined using Equation (4):

$$L = L_{AVG} - (t_{AVG} - t)K_L \qquad \textbf{(4)}$$

It is observed that the loading behaviour with respect to temperature for both Spring and Autumn have a tendency towards Winter loading characteristics, wherein, if the average temperature is lower than the standard average temperature in Winter (including Spring & Autumn), the load demand can be calculated using Equation (5):

$$L = L_{AVG} + (t_{AVG} - t)K_L \qquad \textbf{(5)}$$

However, if the average temperature is higher, the load demand can be determined using Equation (6):

$$L = L_{AVG} - (t - t_{AVG})K_H \quad \textbf{(6)}$$

Given the above models, the coefficients of the Seasonal Forecast Model for Christchurch urban area have been determined as listed in Table 14. The average base load demand and per degree temperature deviation are defined for each season. The load demand forecast is calculated by adding the average base load with the product of the per degree temperature change from the previous day times the specific per degree temperature deviation.

For example, if the average temperature is 5˚C on a Workday in Winter, the load demand will be 422.4 + (6.6-5) × 18.3 = 451.7 MW. If the average temperature is 17˚C on a Saturday in Summer, the load demand will be 230 + (17-16) × 2.7 = 232.7 MW.

Table 14 *– Christchurch Seasonal Forecast Model –(A) Monday, (B) Saturday and (C) Sunday and Public Holidays*

Season	(A) Workday Forecast Model				(B) Saturday Forecast Model				(C) Sunday & P. H Forecast Model			
	t_{AVG}	L_{AVG}	K_H	K_L	t_{AVG}	L_{AVG}	K_H	K_L	t_{AVG}	L_{AVG}	K_H	K_L
Spring	10.7	332.3	1.6	11.8	11.3	269.5	2.3	9.7	11.4	262.4	2.3	10.1
Summer	15.9	282	2.7	1.8	16	230	12.3	1.3	16.2	216.3	5.8	2.5
Autumn	11.4	337.8	2	6.9	12.2	272.8	0.9	11	11.3	269	2.9	11.3
Winter	6.6	422.4	5	18.3	6.4	359.2	3.9	15	6.7	346.3	3.1	14.5

It is recommended to adopt the previous seasonal forecast model to calculate load demand for the first two weeks of the season and the next seasonal forecast model for the last two weeks of the season. For example, in autumn, the Summer model is still required to portray its load behaviour in the first two weeks of June. Likewise for the last two weeks of August, the Winter model should be used to obtain the load demand forecast.

5. FUTURE WORK

For the completeness of this paper, the forecasting model should be extended to include the Christchurch rural area loads, which has summer peaking characteristics with high sensitivity to rainfall and temperature, due to farming irrigation. This would allow prediction of the electricity demand and energy consumption for the entire Christchurch region to assist with Orion's load management and planning.

6. CONCLUSION

Accurate load forecasting is crucial for electric utility companies in a competitive deregulated environment. In this paper, an alternative forecasting method is explored, implemented and developed to adapt to the Christchurch urban area's load structure and characteristics. In this project, a Day-type Correlation model is recommended for the mid-term demand or energy forecast and a seasonal model is more suitable for short-term load forecasting with the precision to forecast daily load demand.

The average load demand and energy consumption forecast is calculated for 2008 with consideration of the number of Workdays, Saturday, Sunday and Public Holidays respectively in each month in New Zealand using a standard day-type correlation method. However, this ignores the underlying growth trend. In order to improve the Day-type Correlation model, forecasts were made of the load demand in every month in 2008 using a monthly growth rate, resulting in higher but better values than those obtained from the day-type model. The limitation is that the model can only forecast mid-term load demand or energy consumption, due to the availability of the vertical and horizontal growth rate between the same and different day types. A Seasonal model was designed from which the daily average load demand, based on the change of the temperature with different day-types, can be forecasted.

7. AKNOWLEDGEMENTS

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APPENDIX-Nomenclature

Algebraic symbols	
L_W	Average Workdays demand(kW)
n_W^S	Standard Workdays
n_W^A	Actual Workdays
L_{Sat}	Average Saturday demand(kW)
n_{Sat}^S	Standard Saturdays
n_{Sat}^A	Actual Saturdays
$L_{Sun+Hol}$	Average Sunday/Public Holiday Demand (kW)
$n_{Sun+Hol}^S$	Standard Sundays/Public Holidays
$n_{Sun+Hol}^A$	Actual Sundays/Public Holidays
S_{CDD}	Cooling Degree-Days Sensitivity
n_{CDD}^S	Standard Cooling Degree-Days
n_{CDD}^A	Actual Cooling Degree-Days
S_{HDD}	Heating Degree-Days Sensitivity
n_{HDD}^S	Standard Heating Degree-Days
n_{HDD}^A	Actual Heating Degree-Days
S_{WW}	Wet Weather Sensitivity
n_{WW}^S	Standard Wet Weather Days
n_{WW}^A	Actual Wet Weather Days
L	Forecast load demand(MW)
L_{AVG}	Average load demand(MW)
t_{AVG}	Standard average temperature in Seasonal Forecast Model (˚C)
t	Real average temperature (˚C)
K_H	Load coefficient when average temperature is higher than standard average temperature (MW / ˚C)
K_L	Load coefficient when average temperature is higher than standard average temperature (MW / ˚C)
Superscript	
S	Standard
A	Actual
Subscript	
W	Weekdays
Sat	Saturdays
$Sun+Hol$	Sundays/Public Holidays
$CDDs$	Cooling Degree-Days
$HDDs$	Heating Degree-Days
WW	Wet Weather
AVG	Average
H	Average temperature is higher than standard average temperature
L	Average temperature is lower than standard average temperature